

# MEMBRANE PROCESSING

## a new tool for whey disposal

Cheese processors are finding it harder and harder to share Miss Muffet's taste for curds and whey. The reason is that whey presents a major disposal problem. Worldwide production of fluid whey has been estimated to be between 50 and 75 billion lb. annually. Even though much of the nutritional value of milk resides in the whey, its bulk and perishability make processing and drying by conventional methods a marginal venture. Thus, whey has long been treated as a waste product, but anti-pollution concern is forcing cheese manufacturers to look towards utilisation rather than disposal.

During recent years, two related membrane processes—reverse osmosis (RO) and ultrafiltration (UF)—have received considerable attention as new tools for economically treating whey. Both RO and UF are based on the ability of polymeric membranes to discriminate between molecules on the basis of size and/or chemical composition. The basic principle of RO has been discussed in an earlier issue of *Dairy Industries*<sup>6</sup>. Although the terms RO and UF are often used synonymously, they differ in that RO involves solute-solvent separations of ionic molecules while UF is essentially a filtration which separates molecules having significant differences in size. In RO, virtually all species except water are rejected by the membrane and are concentrated; in UF, the membrane is permeable to both solvent and low molecular weight solutes,

but is impermeable to higher molecular weight solutes. By controlling pore size during fabrication, UF membranes can be made to fractionate effectively components of the whey. One may produce a variety of useful product concentrates from whey by using different combinations of membranes and different sequences of processing.

### EQUIPMENT

Currently one may choose from among 12 to 15 manufacturers an equal number of systems, differing largely in the design of support structure used as backing for the membrane. These include the plate and frame and spiral wound modules

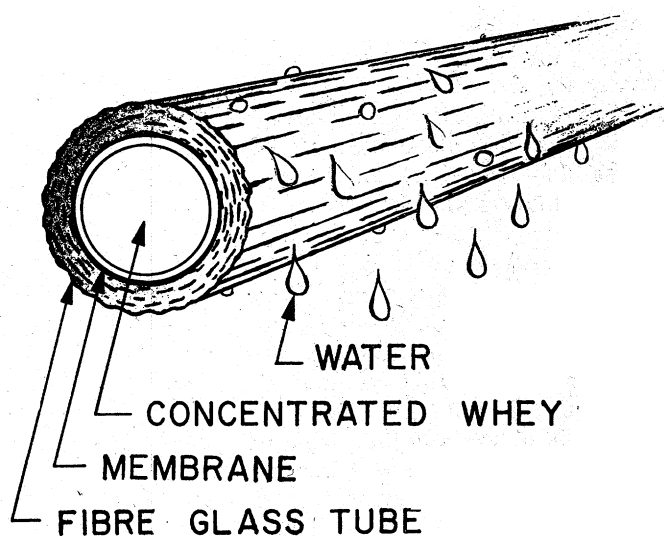


Fig. 1. Membrane processing tube

described earlier by McKenna<sup>6</sup>. Most, however, are variations of the tubular design which has proved to be the most successful in food applications. As illustrated in Fig. 1, a hollow support tube, generally 1.25 to 2.54 cm. diam., is lined with a continuous membrane and the feed liquid is circulated through the tubes at the desired pressure. The product water (permeate) passes through and is collected from the outside surfaces of the tubes. The concentrate is retained

\*Research Food Technologist, Eastern Marketing & Nutrition Research Division, US Dept. of Agriculture, Beltsville, Maryland 20705.

in the tubes and is collected from the final tube. Although a few systems utilise individual tubes, most use a single header to group a number of tubes to form a module. Any number of modules can then be arranged in parallel series to give great latitude in unit size.

### WHEY CONCENTRATION

Numerous reports concerning concentration of cheese whey by RO have appeared in recent literature<sup>1,2,3,4,5,6</sup>. Initial work was carried out by the Agricultural Research Service, US Department of Agriculture, with a tubular unit and membranes manufactured by Calgon-Havens Systems, San Diego, Ca.\*\* The membranes, designated 5A and 3A, had NaCl rejection values of 95.5% and 75% respectively. Typical data from those experiments are summarised in Table 1. The tighter membrane produced a very clean permeate, containing only 0.06% total solids, while permeate from the looser membrane contained 0.30% total solids. When converted to dry weight to compare mass balance, the data for the 5A membrane showed a loss in the permeate of 0.72% of the total solids, 2.2% of the ash and 0.64% of the lactose. Similarly, loss through the 3A membrane was 3.69% of the total solids, 23.72% of the ash and 1.28% of the lactose. By subtracting NPN from total nitrogen, we can see that there was no loss of actual protein; the nitrogen loss was entirely from small nitrogenous compounds. The increased loss of solids in the permeate from the 3A membrane was accompanied by substantially greater water passage rates and, thus, better economics. Many processors may find it advantageous to accept the penalty of permeate with a higher BOD in order to achieve the higher processing rates.

### WHEY FRACTIONATION

The second major application for membrane processing is fractionation. In order to produce a protein concentrate, one may use a UF membrane which is permeable to lactic acid, lactose, ash, and short chain polypeptides, but impermeable to the whey proteins. Assuming zero rejection

of the permeable components, removal of water from the whey would result in removal of these components in the same proportion as the water. Such a process would produce a high protein to lactose ratio in the concentrate, the ratio depending only on the degree of volumetric reduction attained. Table 2 indicates the product composition which may be obtained from a typical whey at various degrees of water removal by UF. These data are theoretical calculations of Fenton-May<sup>2</sup> assuming complete rejection of whey protein and zero rejection of all other constituents of the whey. In practice, however, these absolute separations have not been achieved. Typical results from experiments in our labs using Calgon-Havens type 215 membranes are shown in Table 3. The rejection values of 97.4% for

TABLE 1. Analytical data from reverse osmosis concentration of 309 kg. Cheddar cheese whey

		Membrane type*	
		5A %	3A %
Total solids	Whey	6.53	6.53
	Concentrate	31.40	32.60
	Permeate	.06	.30
	% Loss†	.72	3.69
Ash	Whey	.61	.61
	Concentrate	2.88	2.55
	Permeate	.02	.18
	% Loss†	2.22	23.72
Lactose	Whey	4.39	4.39
	Concentrate	20.98	22.20
	Permeate	.04	.07
	% Loss†	.64	1.28
Total nitrogen	Whey	.13	.13
	Concentrate	.64	.63
	Permeate	.003	.010
	% Loss†	1.74	7.27
NPN	Whey	.040	.040
	Concentrate	.200	.210
	Permeate	.003	.009
	% Loss†	5.8	17.0

\* Calgon-Havens. NaCl rejections: 5A, 95.5%; 3A, 75%

† Calculated from dry weights

TABLE 2. Compositions of whey concentrates which can be obtained by ultrafiltration\*

Component	Water removal				
	0	80	90	95	97.5
	% by weight of components				
Total solids	6.6	9.1	11.9	17.1	26.0
Protein	0.67	3.3	6.3	11.9	21.2
NPN compounds	0.2	0.2	0.2	0.2	0.2
Lactose	5.0	4.9	4.7	4.4	4.0
Lactic acid	0.2	0.2	0.2	0.2	0.2
Ash	0.5	0.5	0.5	0.4	0.4
Protein: lactose ratio	1:7	2:3	7:5	3:1	5:1

\* Data of Fenton-May<sup>2</sup>

TABLE 3. Dry weights of ultrafiltration fractions from 617 kg. of cheese whey

	Original whey	Concentrate	Permeate	Quantity in permeate	Rejection*
	kg.	kg.	kg.	%	%
Total solids	44.76	11.36	33.96	75.8	17.3
Lactose	29.00	6.29	22.64	78.0	13.4
Ash	3.77	0.49	3.29	87.3	4.8
Lactic acid	3.21	0.35	2.78	86.5	3.9
Total nitrogen	0.89	0.67	0.23	25.4	71.8
NPN	0.31	0.10	0.21	68.1	24.3
Protein†	3.71	3.67	0.09	2.3	97.4

\* Based on % water removal

† Protein nitrogen × 6.38

\*\*Trade names are mentioned for identification, implying no endorsement.

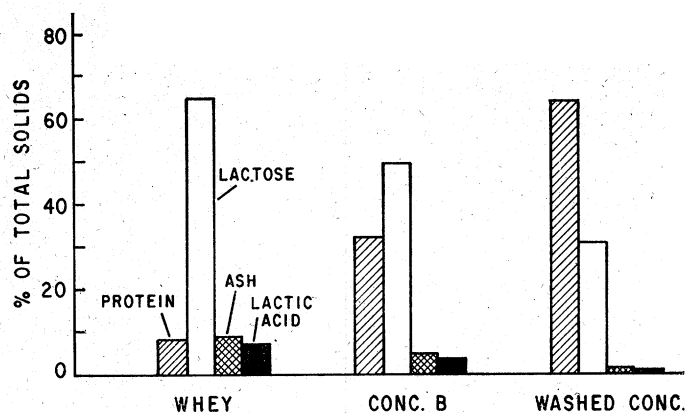


Fig. 2. Comparison of ratio of solids of whey and ultrafiltration fractions

protein, 4.8% for ash, and 3.9% for lactic acid, though not perfect, were very satisfactory, but the 13.4% for lactose was slightly higher than desired. The effect, of course, is a concentrate with a lower protein to lactose ratio than would have been obtained had the membrane been more permeable to lactose.

Higher protein levels can be obtained by adding water back to the concentrate and repeating the UF procedure. This, in effect, washes out additional solids from the concentrate. A comparison of dry weight percentages of the original whey, the first concentrate (B), and the 'washed' concentrate are pictured graphically in Fig. 2. The initial UF procedure resulted in a 'skim milk equivalent' concentrate containing about 35% protein and about 50% lactose while the dilution and recycling procedure resulted in a concentrate containing 65% protein. If membranes can be improved to permit 0% rejection of lactose, rather than the 13.4% reported here, concentrates with significantly higher protein could be produced. It is believed that such membranes have become available since the beginning of these studies.

#### OUTLOOK FOR RO/UF

There are still a number of uncertainties in trying to predict the future of RO/UF in the dairy industry. Membrane processing appears to offer economical means of handling both the waste disposal and by-product recovery aspects of whey. The unknown factors at this time involve

economics and reliability and life of the membranes. Under contract with the US Department of Agriculture, the H. P. Hood Co., Boston, Mass., is now determining the feasibility and economics of both RO and UF on a commercial scale. The Crowley Milk Co., supported by the Water Quality Office, US Department of Interior, recently finished pilot plant tests, and plans call for construction of a 136,000 kg./day plant in the near future. Conclusion of these programmes should answer many of the questions still confronting us. The field of membrane technology is rapidly advancing and is expected to play a big part in solving our whey disposal problems.

#### REFERENCES

- 1 Dunkley, W. L. *Symposium on Reverse Osmosis*, US Dept. of Agriculture, Albany, Ca., 1969.
- 2 Fenton-May, R. I. *et al. J. Food Sci.*, 1971, **36**, 14.
- 3 Marshall, P. G. *et al. Food Technol.*, 1968, **22**, 969.
- 4 McDonough, F. E. *Food Eng.*, 1968, **40**, 124.
- 5 McDonough, F. E. & Mattingly, W. A. *Food Technol.*, 1970, **24**, 88.
- 6 McKenna, B. M. *Dairy Ind.*, 1970, **35**, 755.